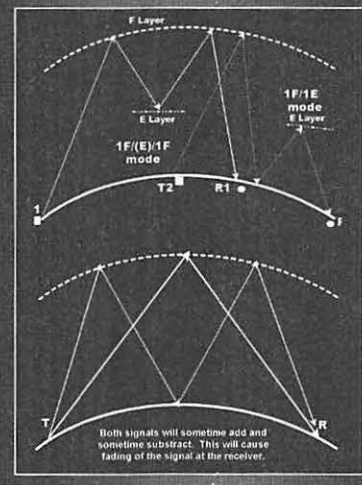
# Propagation Modes from ELF to SHF




By Jacques d'Avignon

*You can hear it just about anytime, anywhere in the world: "This is London calling. You are tuned to the Pacific Service of Radio Australia." So, given the distances involved and the earth's curvature, how do they do that?*

Any time you tune your shortwave receiver across the various shortwave bands, "London calling" is the type of announcement that you will hear on the hour and the half hour. Occasionally you will also hear some more exotic announcement in unusual languages. Since radio waves travel in a straight line and the Earth is round, how do these transmissions reach you halfway around the Earth?

Radio waves travel through the air (propagate) in several different ways. Typically, a propagation mode that works very well in one part of the radio frequency spectrum will not necessarily work well, if at all, for other frequencies. Let's make a list of the main modes and then we will discuss their uses and limitations. The following are the most common modes of propagation.

**Ground Wave Propagation:** mostly encountered in the low frequency (LF) beacon and in the medium frequency (MF) broadcast band area of the spectrum.

**Line Of Sight (LOS) propagation:** the preferred mode of propagation for very high frequency (VHF), ultra-high frequency (UHF), super-high frequency (SHF), and extra-high frequency (EHF) bands.

**Ionospheric refraction (reflection):** the "normal" propagation mode for the high frequency (HF) part of the spectrum. In certain very specific circumstances, this mode can function as high as 50 MHz.

**Near Vertical Incidence Skywave (NVIS):** special ionospheric propagation mode used in the lower HF band, 2 to 6 MHz (called the Tropical Bands), utilizing the ionosphere to reflect an HF signal for communication purposes inside the "skip zone."

## Ground Wave Propagation

The mode that the AM broadcast stations use to reach their audience, the ground wave will hug the ground and reach out from the

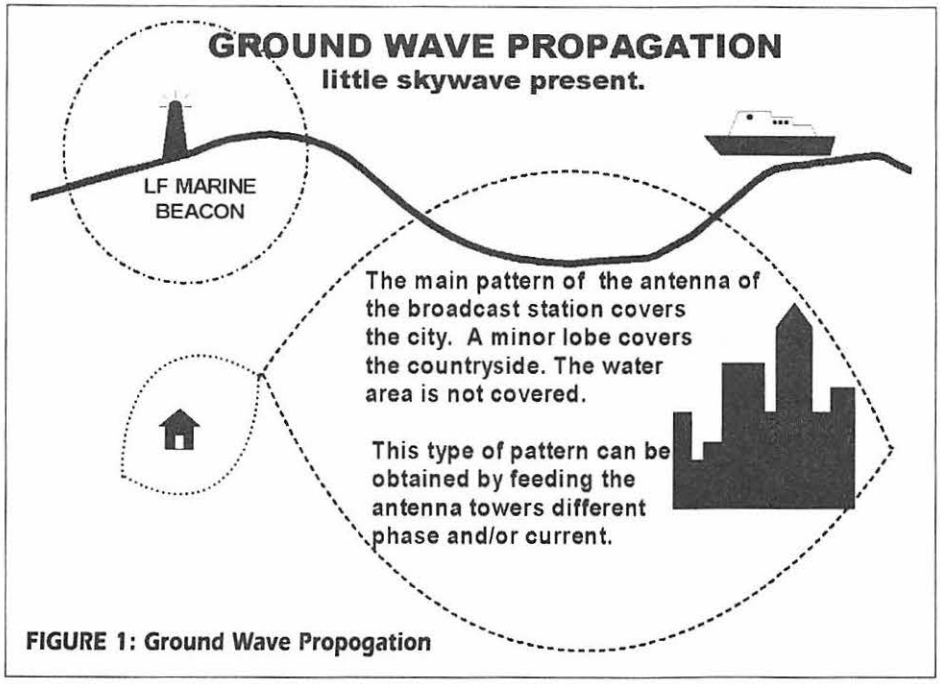

GROUND WAVE PROPAGATION
little skywave present.
LF MARINE BEACON
The main pattern of the antenna of the broadcast station covers the city. A minor lobe covers the countryside. The water area is not covered.
This type of pattern can be obtained by feeding the antenna towers different phase and/or current.

**FIGURE 1: Ground Wave Propogation**

transmitter site, especially in the daytime. The radiation pattern can be modified by using more than one tower so that the waves will travel further in certain directions and be heard only faintly in others. Often, the day and night patterns are different in order to protect other stations on the same frequency but geographically far removed. Broadcast stations try to have the least amount of skywave component in their signals: their market is close by and most of the power should be directed in the ground wave component. (Figure 1)

The marine and/or aero beacon stations also use this type of propagation. Their signals are designed to be used close to the station. But even with the special antenna system used by these stations, it is practically impossible to remove all the sky-wave components of these signals. Thus, LF beacon signals are occasionally heard very far from their intended target.

Another major user of ground waves is the GWEN system (Ground Wave Emergency Network), installed and operated by the USA armed forces in the event the ionosphere should be disrupted by a force such as a nuclear bomb. This system operates in the vicinity of 160 kHz area of the spectrum.

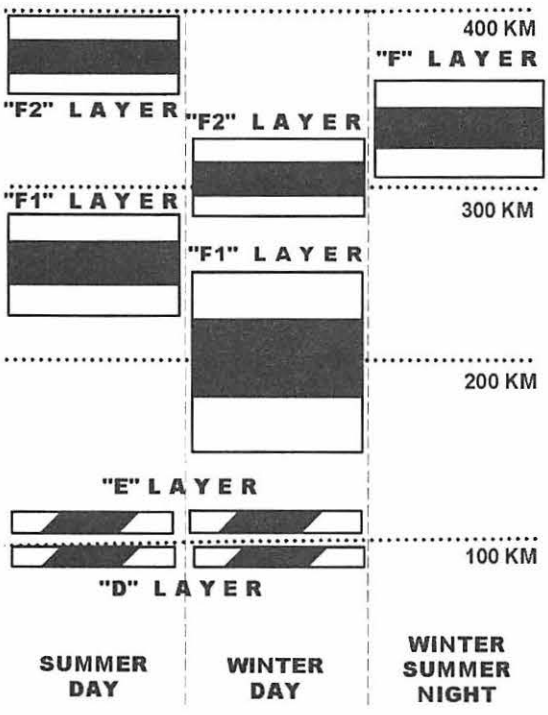



**FIGURE 2: Ionospheric layers, simplified**

## Line Of Sight

This is the normal mode for FM/TV broadcasts, microwave networks, satellite up and down links, and most of all, the transmissions above 50 MHz, including radar. In this type of propagation, both transmitter and receiver have to "see" each other directly or indirectly. This is why your scanner antenna should be installed as high as possible.

Indirect contact between the antennae can be accomplished, in the case of a microwave network, by bouncing the signal off large metal plates, or a mountain side, so that the signal will turn corners and be picked up by another relay site. The most interesting example of this type of installation that I have seen is located along the Alaska Railroad south of Anchorage. They found it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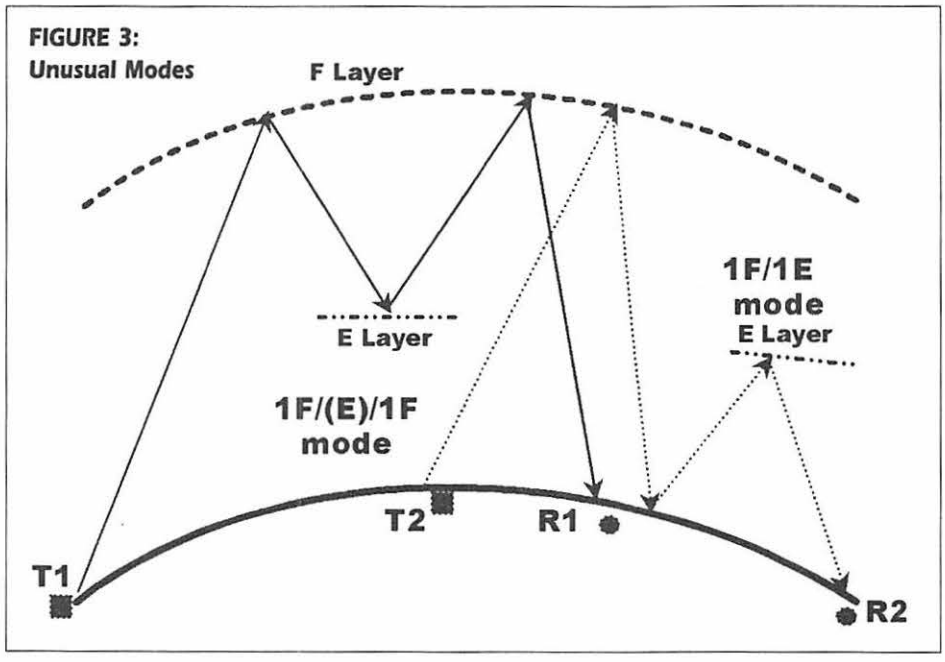



easier to use this mirror system to turn corners than to build additional sites in very rugged terrain!

This type of propagation is normally immune from the weather problems at the low end of the range, but as you move up in frequency, you will encounter absorption by rain, fog, and snow. As you reach the upper limit of the microwave spectrum, most of your power will be absorbed by the water vapor in the atmosphere in the same manner as your broadcast ground wave signal will be absorbed by jungle vegetation.

### HF ionospheric refraction.

This is the normal propagation mode that will carry shortwave transmissions to far places. Around the globe we have a few ionized layers that can refract the HF frequencies. The nature of these layers and how well we can use them to refract the HF waves are influenced by (1) the daily state of the sun, (2) where we are located in the sun's 11 year cycle, and (3) the time of day, plus a few other variables. The number of layers and their respective altitude vary according to the time of day and season of the year. Incidentally, the time of day referred to is the time of day halfway between the transmitter and the receiver, as it is here that the signals will normally be refracted on the way between the transmitter and you!

During the daylight hours, the ionosphere is comprised of four layers: D and E located below 100 kilometers, F1 and F2 between 150 and approximately 300 kilometers. There will be a difference in altitude for each layer between winter and summer. At night, no matter what the season, the D layer disappears, the E layer becomes very weak, and the F1 and F2 layers combine into one single F layer located between 300 and 400 kilometers. (Figure 2)

Refraction by the nighttime F layer is responsible for most of the signals that we hear from around the world, and that includes the signals received from the AM broadcasting stations and from aero/marine beacons that have very little skywave components in their signals. Obviously, this layer is the mirror that lets us hear the international broadcasters' message on shortwave. However, because of the geometry of the signal path in this type of propagation, a "skip zone" extends between transmitter site and the first bounce back to earth. There is a mode (NVIS) that will fill this void, which we will examine later.

During the day, the D, E, and F1/F2 layers are responsible for the refraction, but it is difficult to differentiate exactly which layer does the actual refracting on a specific path. It is possible that the signal is reaching you by refraction by more than one layer; this will cause some unusual audio effects, for which there is no easy fix.

Simple refraction schemes such as 2F, 2E, 1F, etc. are common. Some most "interesting" schemes such as 1F/1E/1F, 1F/(E)/1F can also be present. (Figure 3) The amount of refraction and how the wave is refracted does have a great influence on the quality of the signal that will reach you. A good example of the effect of such composite refraction schemes is fading.

### Fixes for Fading

Among many possible causes, fading can be the result of the same signal arriving by two different routes: an F and an E layer refraction, for example. Or, the signal may be refracted by one layer, but take two different paths, such as 1F and 2F, thereby phasing itself in and out. This can be caused by the transmitting antenna's wide beamwidth where

*Continued on Page 26*

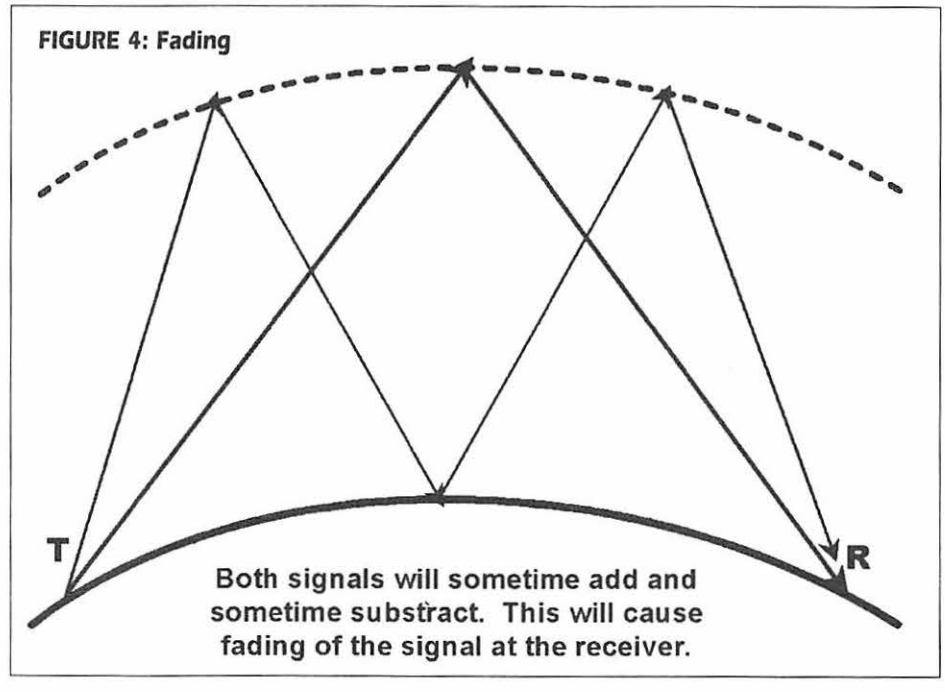
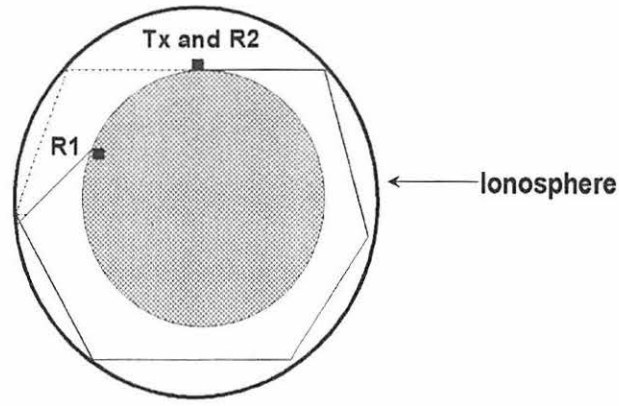


FIGURE 4: Fading
T
R
Both signals will sometime add and sometime substract. This will cause fading of the signal at the receiver.

some of the energy is broadcast at a low angle, giving a 1F path, while some energy is radiated at a high angle for a 2F route. (Figure 4)

The first type of fading is very difficult to avoid at either the receiving or transmitting site. The second situation could be helped at the transmitter site by using an antenna with a very narrow beamwidth, thus concentrating the maximum energy at a specified radiation angle. But one of the most effective cures to fading is diversity reception.

**FIGURE 5: Chordal Propagation**




**The signal transmitted from "T" can be received at "R1" without a single bounce off the earth. The same signal can also be received at "R2" after a trip around the world. At "R2", the reception delay was measured at 138 milliseconds. If there had been 35 hops, the delay would have been measured at 160 milliseconds.**

Diversity reception is an old technique used to reduce the problems of fading on shortwave. This technique was used on a large scale when many of the overseas telephone calls were made on HF circuit. (Now, don't say: "That was way before my time!" because this technique is still being used today!) Two of the most interesting diversity techniques are frequency diversity and space diversity reception.

In both types of diversity reception, it is necessary to feed the output of two receivers into a polling device that will feed the speaker/line the best signal. The frequency diversity technique relies on the fact that fading does not occur simultaneously on two frequencies separated by just a few MHz. While the signal level is dropping on one frequency, it is rising on the other frequency. Space diversity uses two antennae separated by 10 to 20 wavelengths, and operates on the principle that the same frequency will not fade at the same instant in both antennae.

There are limitations to the frequency diversity system when it is used for high speed RTTY or facsimile. There may be enough time difference between the two signals (if one is a 1F and the other is a 2F signal, for instance), to cause major distortion problems in the signal being fed to the decoding device.

In space diversity one limitation is the space requirement for the installation. You need a lot of real estate to install all your antennae. This could be very expensive, especially if you are using rhombic antennae that could already measure 5 to 10 wavelengths!

### Divergent Paths

As a subset of the ionospheric propagation mode, three types of "unusual" propagation geometry are worth our attention. These three modes are: chordal propagation, ducted ionospheric propagation, and near vertical incidence skywave (NVIS).

In my listing at the beginning of this article, I have specifically separated NVIS because it is a mode that is much used and well understood. The two other subset modes—chordal and ducted—are not as well understood and do not appear to have any special use.

The chordal mode is graphically described in Figure 5. We know that there are no ground reflections along the path, as the delay is only 138 milliseconds between transmission and reception after the signal has made a full trip around the world. If there were multiple hops along the way, as expected in a normal ionospheric propagation mode, the delay would be at least 160 milliseconds.

This type of propagation is very similar to sound propagation along the vaulted ceiling of certain cathedrals. You speak facing the wall, and across the church a person can hear what you are whispering by listening to the wall! Your voice is carried along the vaulted ceiling, because no one under that ceiling can hear what you are saying.

The ducted mode, Figure 6, apparently occurs most often at frequencies between 13 and 18 MHz, and the conditions for insertion and extraction of the signal to utilize the mode are fairly stringent. Some research was done on this mode in the 1970s, but it does not appear as if there is any viable use for this mode nor even a good explanation of how it occurs.

Figure 7 describes graphically how the Near Vertical Incidence Skywave (NVIS) works in practice. This mode carries other names also: showerhead mode, district mode, and the tropical mode. The origin of the name "showerhead" is obvious: the signal is sent

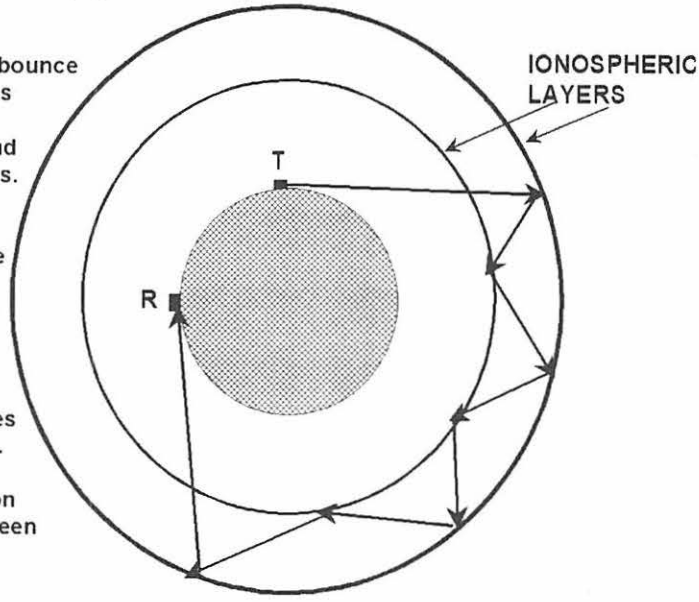
**FIGURE 6: Ducted Propagation**

**The signal will bounce between various layers of the ionosophere and within the layers.**

**No known commercial use for this type of propagation.**

**Difficult to achieve and to predict, but does occur regularly.**

**Little attenuation measured between "T" and "R".**



straight up and comes back down to earth like the water from a showerhead, scattering in a tight circle around the transmission source.

The name "district" is used to describe the mode in Australia, and comes from the fact that it can be used to communicate on HF within an administrative district, which is smaller than a province but bigger than a state in the US (excluding Texas and Alaska!). The Australians outside the larger populated centers depend greatly on HF communications in their daily life and much of the research on this mode was done "down under."

NVIS is also called the tropical mode, as it used for broadcasting in the "Tropical Bands" of the HF spectrum. It is virtually impossible to use ground wave propagation broadcasting in a tropical environment. The vegetation would absorb most of the radiated power within a few miles of the transmitter, so the only recourse is to use HF in the NVIS mode to reach the audience, which is usually scattered over a fairly large geographical area.

However, the NVIS signal is not necessarily confined to the immediate vicinity of the transmitter. The signal will, at times, be heard halfway around the world. For example, just think of the African, South American, and Australian stations in the tropical bands that can be heard in Eastern North America, especially during the northern hemisphere winter!

NVIS has many uses besides being utilized for tropical broadcasting, but it also has some limitations. The main limitation is that the frequency has to be fairly low; normally the frequencies used are in the 2 to 6 MHz area of the spectrum. Any frequency higher than this will result in the signal being lost in space, as the ionosphere would be transparent at such high angle of incidence.

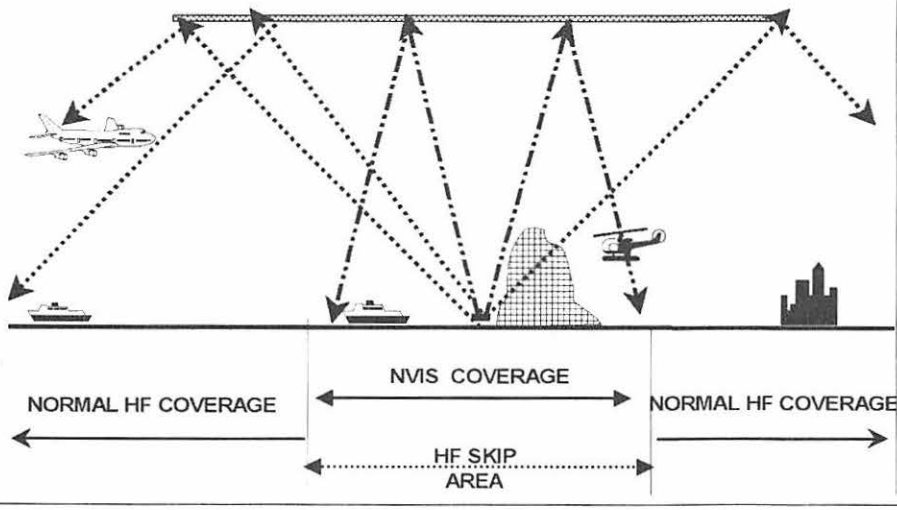
The very high angle of radiation required of the antenna is another limitation. Without it, the signal will be directed too far away from the vertical and will behave as a normal HF transmission. An antenna designed for DX—for example, a vertical quarter wavelength—will not produce the proper pattern for NVIS operation. The simplest antenna for this propagation mode is a horizontal dipole erected about 1/4 wavelength above the ground.

One of the principal uses of NVIS is for communication with ships, helicopters, or aircraft working within the "skip zone" of HF but outside the VHF/UHF line-of-sight path of the coastal or base station. Providing reliable communication with temporary survey camps in remote areas is another use.

There are other exotic propagation modes that have not been discussed here, such as meteor scatter, auroral backscatter, sporadic E, VHF ducting caused by meteorological conditions, and a few more bizarre modes. It should also be remembered that there are no strict barriers between the various propagation modes and at times there will be some overlap between them. The best example of this is when you hear 50 MHz transmissions on your scanner coming from South America, and sometimes from Africa. This should not happen if we look at the theory—50 MHz is at the low end of the VHF range in the spectrum where propagation should be line-of-sight only. Yet, we still hear those transmissions!

So, enjoy your hobby, and do not question too closely exactly how the signal reaches you. Studying propagation modes brings us closer to both the theory *and* the magic that brings us: "This is London calling."

**FIGURE 7: Near Vertical Incidence Skywave (also called "district or shower" propagation mode)**




## Last Minute News Flash:

Jacques d'Avignon reports that the birth of a new sun cycle has been detected by the Caltech observatory on August 12. It appears to be a premature birth! A press release has been sent out by Caltech; watch for more details to come.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